The problem of tracking τ leptons in Geant4

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Problem

- GEANT v4_10_3_p03e is currently used in larsoft and contains a bug in the decay of τ's (tau leptons)

$\rightarrow$ The τ daughter particle 4-momentum vectors are wrong, sometimes causes jobs to crash

- This was found in the atmospheric neutrino background sample for proton decay and $n\bar{n}$-oscillation studies in DUNE, but concerns all events/samples in which τ's are present

- Bug report 1: `https://bugzilla-geant4.kek.jp/show_bug.cgi?id=2053`

- Bug report 2: `https://bugzilla-geant4.kek.jp/show_bug.cgi?id=2061`

Example:

1. τ^- with $E_{\tau^-} \approx 3\,000\,\mathrm{MeV}$ decays into π^- with $E_{\mathrm{kin},\,\pi^-} = 1.3 \cdot 10^{18}\,\mathrm{MeV}$

2. G4EnergyRangeManager is called to choose an interaction model for the π^-:

```
64424 G4EnergyRangeManager:GetHadronicInteraction: counter=3, Ek=1.32623e+18,
64425 *0* low=12000, high=1e+08
64426 *1* low=9500, high=25000
64427 *2* low=0, high=9900
```

3. No model found for the π^-, GEANT4 throws exception:

```
64430 ===> GetHadronicInteraction: No Model found
64431
64432 -------- EEEE ------- G4Exception-START -------- EEEE -------
64433 *** G4Exception : had005
64434       issued by : G4HadronicProcess::PostStepDoIt
```

Workaround in place

- When running GENIE through dunetpc, genie_phyopt is called that forces GENIE to decay τ's via pythia before they are tracked in GEANT4
- We don't want to use this workaround for $n\bar{n}$-oscillation studies since we want to have the τ track

Proposed solution

- 'Short term' solution: move larsoft to GEANT v4_10_6_p01

→ has many improvements and bug fixes, including the decay of τ's (see Krzysztof's presentation)

- But: τ's from neutrino CC interactions are polarized, which affects the momentum spectrum of the τ daughter particles. GEANT4 does not take this into account.

→ Long term solution: track τ in GEANT4, call external package for τ decay (like TAUOLA), track τ daughter particles in GEANT4

The end